AD-752 605

A QUARTZ LAMP BANK FOR THE CHARACTERIZATION OF THERMALLY PROTECTIVE MATERIALS

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Prepared for:

Air Force Materials Laboratory

April 1972

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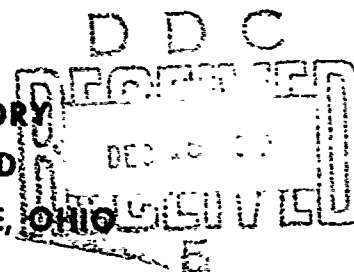TECHNICAL REPORT AFML-TR-72-69

April 1972

AIR FORCE MATERIALS LABORATORY
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

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DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)	2a. REPORT SECURITY CLASSIFICATION
University of Dayton Research Institute Dayton, Ohio 45409	UNCLASSIFIED
	2b. GROUP

3. REPORT TITLE

A QUARTZ LAMP BANK FOR THE CHARACTERIZATION
OF THERMALLY PROTECTIVE MATERIALS

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*
January 1971 to February 1972

5. AUTHOR(S) *(First name, middle initial, last name)*

OLSON, Nicholas J.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
April 1972	46	0

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
F33615-69-C-1385	AFML-TR-72-69
b. PROJECT NO. 7340	
c. TASK NO. 734001	9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*
d.	

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Air Force Materials Laboratory (LNC) Air Force Systems Command Wright-Patterson AFB, Ohio 45433

13. ABSTRACT

This report is an operational description of a quartz tube, tungsten filament lamp bank developed for the characterization of nonmetallic thermal protection materials for high irradiance environments.

The quartz lamp bank is a highly versatile apparatus for providing irradiances of up to 60 Cal/cm^2 sec for various specimen configurations of up to 80 square inches in surface area.

The three operational modes consist of: (a) a pre-set irradiance level, (b) precise regulation in a closed-loop network including a sensing radiometer, and (c) regulation over a programmed irradiance history.

Air jets, a high velocity exhaust, and pressurized components are used to avoid lamp overheating and minimize contamination of critical components by pyrolysis gases emanating from irradiated materials.

The quartz lamp bank has proven to be an adaptable and versatile tool in the exploratory research and development of a variety of nonmetallic thermal protection materials. The classes of characterized materials currently consist of camouflage coatings, fire protection elastomers and textiles, and protective coatings for components subject to thermonuclear irradiance.

DD FORM 1 NOV 65 1473

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Fire Protection Materials						
Nonmetallic Thermally Protective Materials						
Quartz Lamp Bank						
Thermal Radiation Effects						
Thermally Protective Coatings						
Thermally Protective Materials						
Thermonuclear Irradiation Effects						

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N. J. OLSON

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FOREWORD

This report was prepared by the University of Dayton, Dayton, Ohio, under USAF Contract F33615-69-C-1385. This contract was initiated under Project No. 7340, "Nonmetallic and Composite Materials", Task No. 734001, "Thermally Protective Plastics". This work was administered under the direction of the Nonmetallic Materials Division, Air Force Materials Laboratory, with Mr. J. M. Kelble, LN, acting as project engineer.

The technical assistance of Mr. R. Farmer, LNC, is acknowledged with appreciation.

This report covers work conducted from January 1971 through February 1972. The manuscript was released by the author in April 1972 for publication.

This report has been reviewed and is approved.

T. J. REINHART, Jr., Acting Chief
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Air Force Materials Laboratory

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ABSTRACT

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SECTION I

INTRODUCTION

Efficient thermal protection materials are required by the Air Force to guard aircraft components and operating personnel from the intense thermal irradiance of ground fires and thermonuclear weapons. Research on the classes of these thermal protection materials requires an irradiance source for adequate simulation of the critical environmental variables affecting materials response. This report is an operational description of a unique quartz lamp bank specifically developed for the characterization of nonmetallic thermal protection materials for high irradiance environments.

There are numerous environmental variables and a multiplicity of combinations that may affect materials response. Parameters most amendable to laboratory study, such as the irradiance level, spectral distribution and exposure time, vary over wide ranges. Although certain thermophysical properties and thermal stability is relatively fixed for a given material, other variables such as configuration and spectral absorptance can exist over wide ranges.

In order to accommodate the wide spectrum of possible environments and material specimens, it was necessary to design a unique apparatus of high versatility. The quartz lamp bank (QLB) well meets this goal in providing irradiances of up to 60 Cal/cm^2-sec for various specimen configurations of up to 80 square inches in surface area.

The major QLB components consist of two instrumentation consoles, a primary frame for two reflector assemblies, and a power system as shown in the conceptual schematic (Figure 1).

FIGURE 1. Conceptual Schematic

The control/recording console (Figure 2) houses a temperature controller, irradiance programmer, start/stop circuit panel and a timer panel. The console also contains two strip chart recorders for irradiance and temperature histories.

The primary frame (Figure 3) is a large, rectangular device of angle-iron construction. The framework is enclosed on three sides with an asbestos/cement board material and at the top with a high velocity exhaust hood.

The primary frame houses two reflector assemblies using tungsten filament, quartz tube lamps. A high density radiant heater is used for the highest irradiance levels for specimens of up to about ten square inches in area. The radiant heater features air pressurization to reduce lamp overheating and provide cooling for a quartz window. The window is shielded from pyrolysis gas contamination by an air blowby and an exhaust system. The adjoining reflector panel is suitable for up to about 130 KVA input power for specimens of up to about 80 square inches. A specimen table, which is readily retractable, may be mounted beneath either of the two downward-facing assemblies.

The QLB provides a precisely controlled irradiance for each run. There are three modes of operation. In the open-loop mode, the power controller regulates the power system at a pre-set level. In the closed-loop mode, the regulation is improved by use of the negative-feedback principle with a radiometer as the sensing element. A programmer may be further used to program the irradiance in a modified closed-loop mode.

The radiometer is of the Gardon-type and is mounted on the specimen table to "receive" irradiance. Functional accessories include: (a) a high pressure water system for cooling, and (b) horizontal and vertical air jets to shield against contamination from pyrolysis gases. While the radiometer is a key component of the closed-loop operational mode, it serves no controlling function for the open-loop case. The radiometer irradiance history, however, is routinely recorded for each run to insure reliability of operation.

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IRRADIANCE (RADIOMETER) RECORDER

TEMPERATURE RECORDER

START/STOP CIRCUIT PANEL
IRRADIANCE PROGRAMMER
TEMPERATURE CONTROLLER
TIMER PANEL

FIGURE 2. Control/Recording Console
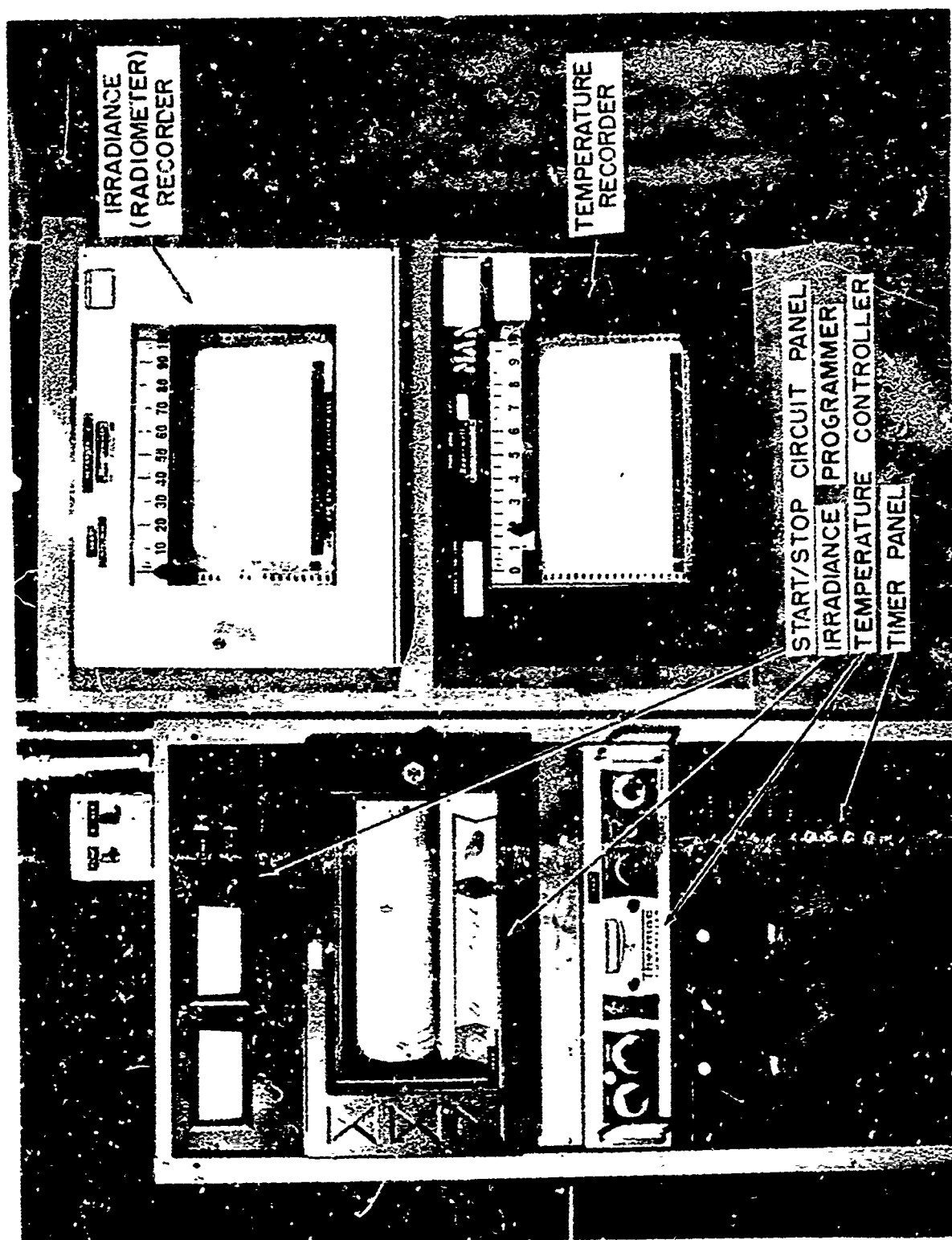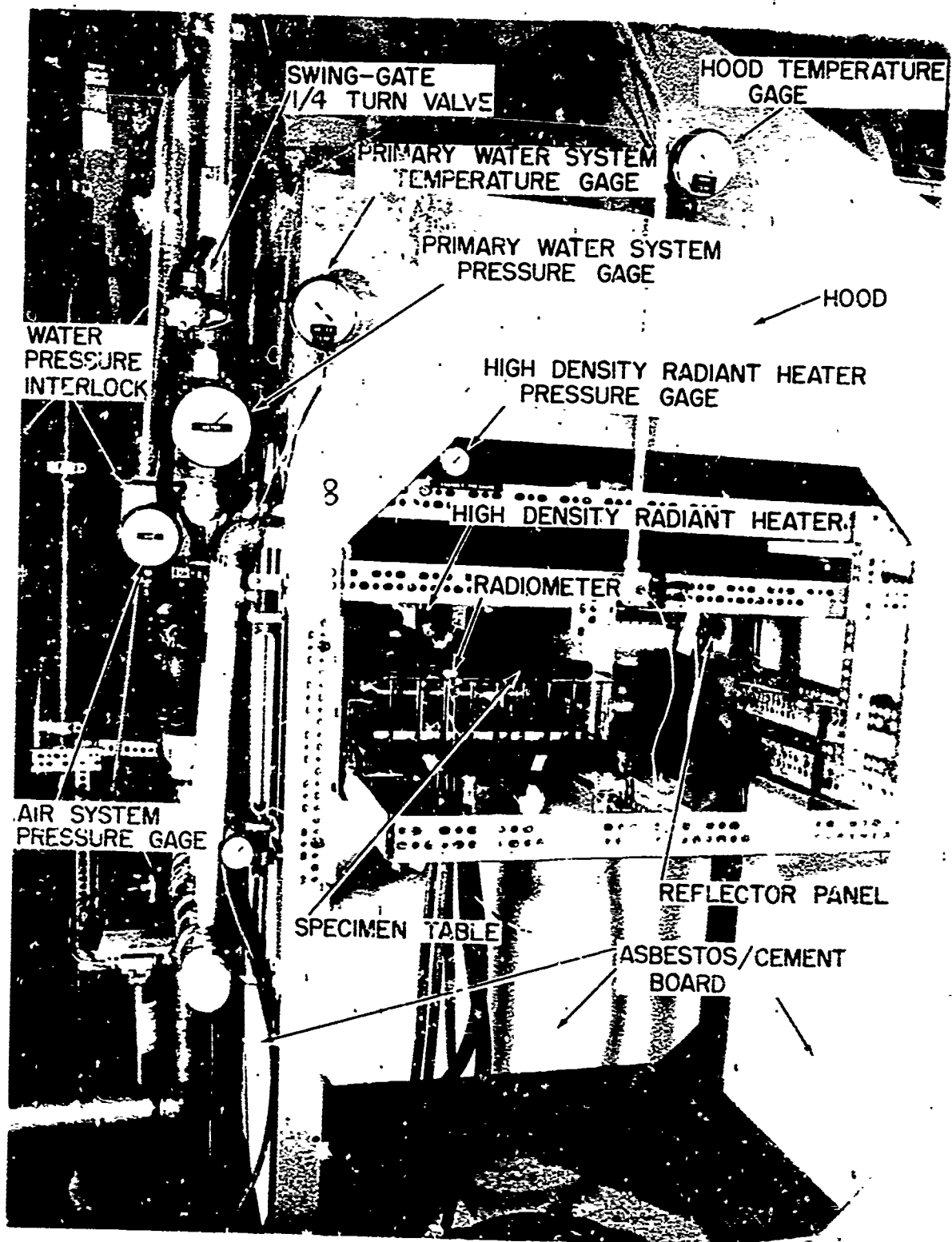
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FIGURE 3. Primary Frame

The QLB has proven to be an adaptable and versatile tool in exploratory research and development of a variety of nonmetallic thermal protection materials. The classes of characterized materials currently consist of camouflage coatings, fire protection elastomers and textiles, and protective coatings for components subject to thermonuclear irradiance.

SECTION II

TRI-PHASER POWER CONTROLLER

An STP Tri-Phaser Power Controller (Figure 4), manufactured by RI Controls, serves as the primary power system. As a power controller for the QLB, the Tri-Phaser regulates a zero-to-maximum proportion of the 3-phase line voltage and applies this voltage to the reflector lamps in response to a dc control signal of 0 to 5 volts. In operation, the Tri-Phaser further serves as an efficient voltage regulator with a high immunity against line transients or power surges.

The Tri-Phaser is nominally rated at 277 KVA and a maximum of 330 amperes for 3-phase loads. The unit is actuated from a 3-phase, 480 vac line source provided with a safety switch box and fusing. The nominal capacity of the line source is 132 KVA. This rating is below the capability of the Tri-Phaser but remains adequate for operation of the reflector assemblies.

The amplifier of the Tri-Phaser is augmented by special circuitry to modify the Thermac control signal. This change results in three types of rise time characteristics and permits many combinations of rise time to peak load for varying operational requirements. One of the three rise time modes may be selected by changing the position of a jumper wire inside of the Tri-Phaser firing circuit chassis. In the "Fast" mode normally used, power is applied with zero delay after any error signal has been sensed by the Thermac. In the "Ramp-Clamp" mode, the step input signal from the controller is converted to a ramp input of 0.3 sec duration causing the firing angle to be advanced from 0 to maximum in 0.3 seconds.

When a delay is desired for applications where the controller and the load may be damaged by instantaneous operation, the "Lamp-Clamp" mode is used. In this mode the step input signal is converted to an integrated signal of from 4 to 5 seconds duration.
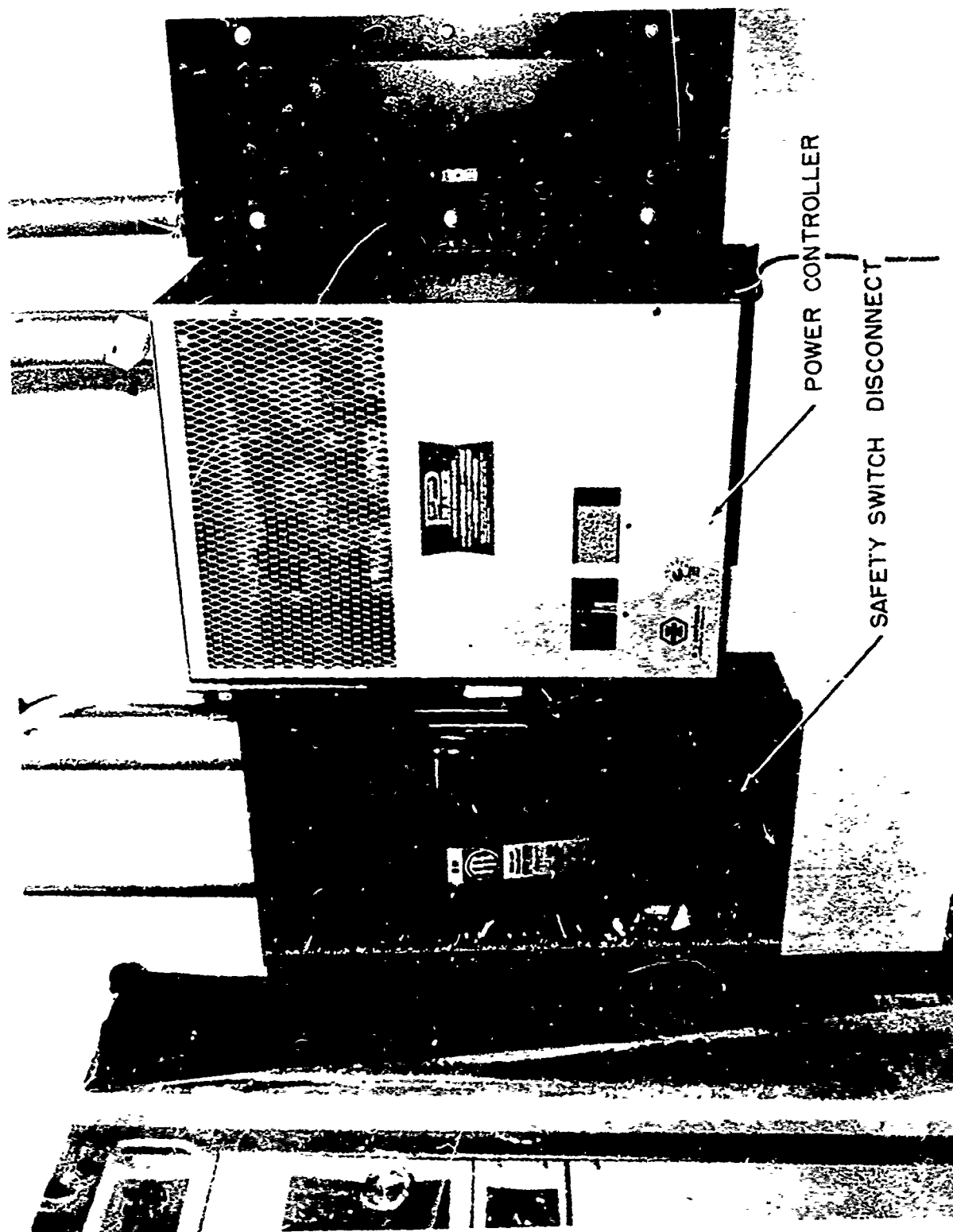
POWER CONTROLLER

SAFETY SWITCH DISCONNECT

FIGURE 4. Power Controller

SECTION III

CONTROL CONSOLE

A.   Thermac Temperature Controller

The Thermac Temperature Controller (Figure 5), manufactured by RI Controls, is the basic QLB control device. There are three types of Thermac operation. When a set-point device is used, the QLB operates as a closed-loop system with precision control and regulation of the Tri-Phaser in maintaining a constant irradiance. The Thermac may also be used to manually establish the power level for the Tri-Phaser, but without control and regulation, resulting in open-loop operation of the QLB.

In "remote" control the Thermac is utilized to provide specific programmed irradiance histories in a modified closed-loop mode.

The closed-loop or "set-point" operational system uses a radiometer to generate a voltage that is proportional to the sensed irradiance. This dc voltage is compared against a command voltage established by the Thermac set-point. Any unbalance results in a difference change in the Tri-Phaser control voltage. The error voltage, with a polarity corresponding to the error direction, effectively adjusts the lamp power to maintain a constant irradiance.

In the open-loop or "manual" system of operation, the radiometer is not effective in controlling irradiance and there is no Thermac error voltage. The power level for Tri-Phaser regulation is established by the setting of the Thermac manual control.

The Thermac controls the proportional band and limits the maximum voltage for Tri-Phaser operation in both open and closed loop systems. The width of proportional band control is a function of the gain setting. Increasing the gain narrows the band; decreasing the gain widens it. For optimum control, the gain must be set at a point consistent with system stability. The limiter

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FIGURE 5. Temperature Controller

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enables the maximum voltage to be limited to a percentage of the operational range. In addition to limiting the peak load, the rise time to peak load is an inverse function of the limiter setting.

B.   Data-Trak Programmer

The Data-Trak Programmer (Figure 6), manufactured by RI Controls, is an electro-mechanical instrument designed to position the shaft of a rotary output potentiometer in accordance with variations in a preplotted program attached to a rotating drum. This function is accomplished through an electrostatic curve following system. A desired program is scribed on the metallized surface of a special program chart with a sharp stylus. The stylus removes a fine line of metal from along the curve dividing the chart into two electrically isolated conductive planes. The program chart, mounted on a drum, is then rotated at (1/3) inch/sec. The two isolated planes are separately energized by oppositely phased ac voltages. These voltages establish a gradient across the gap created by the program curve. As the drum is rotated, a probe, driven by a servo-system, follows the curve. The shaft of the rotary output potentiometer is mechanically coupled to the probe. As the probe follows the curve, the position of the wiper on the potentiometer is changed accordingly, changing the resistance in direct proportion to changes in the program. The potentiometer is connected to the Thermac Temperature Controller and controls the voltage output from the controller in the "remote" mode.

The development of a program of irradiance for use on the Data-Trak is accomplished through a series of actual radiometer exposures. The Data-Trak is not energized allowing the probe to be moved by hand without damage to the mechanism. The mode of operation is "remote" and irradiance levels are controlled by hand positioning the Data-Trak probe. As desired levels are observed on the radiometer recorder, the positions of the probe are marked on the program chart. The chart is then removed and the curve is scribed using the marks as one axis and time as the other.
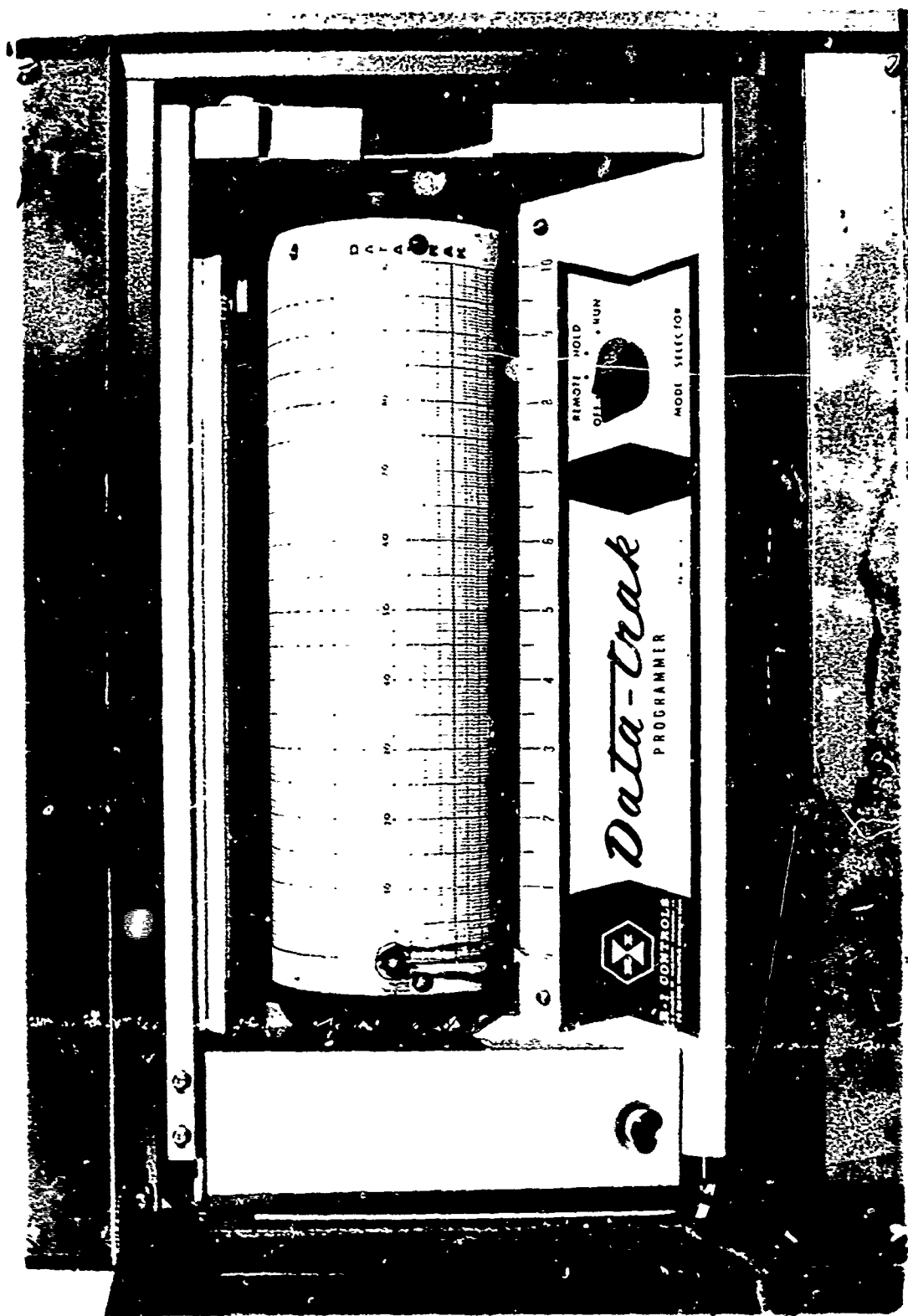
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FIGURE 6. Programmer

When a programmed run is to be made using the Data-Trak Programmer, the Manual mode is used. With the Thermac input control at the "Remote" position and the Data-Trak program starting at "0" (pen farthest to the left), the Start button may be pressed. The pressing of the Start button does energize the STP Power Controller but no power will be applied to the lamps until the program calls for power. The Data-Trak control is moved to the Run position to start the drum rotating. The run will actually be started when the program starts its call for power to be applied to the lamps.

C.   Start/Stop Circuitry

An electro-mechanical system was constructed for promptly starting and stopping a run. In conjunction with the "Fast" Tri-Phaser circuitry and the Thermac proportional band and limiting controls, the system results in minimal power and irradiance transients. The transients are minimized during the time to and from peak load, as well as during heating.

The control console shown in Figure 2 contains most of the system components and associate wiring. A Manual/Timer operational mode switch, Start/Stop quick release buttons, and Standby/Run indicator lights are located on the Start/Stop circuit panel. The Timer Panel contains the additional components of a timer selector switch, run lights, and two timers. A Tri-Phaser power interlock and a water pressure interlock are also used as safety devices.

The Start/Stop circuitry (Figure 7) was designed around a run relay (K_1) component of the Power Controller. Power is available for the reflector lamps when this relay is energized. As shown by Figure 7, K_1 is normally relaxed when power is applied from the line safety switch to the 440 vac step-down transformer T_{2-1}. With K_1 relaxed, the relay contacts K_{1-1} are closed, which lights the Standby indicator light. In addition, K_3 is energized which opens the circuit for the two timers.
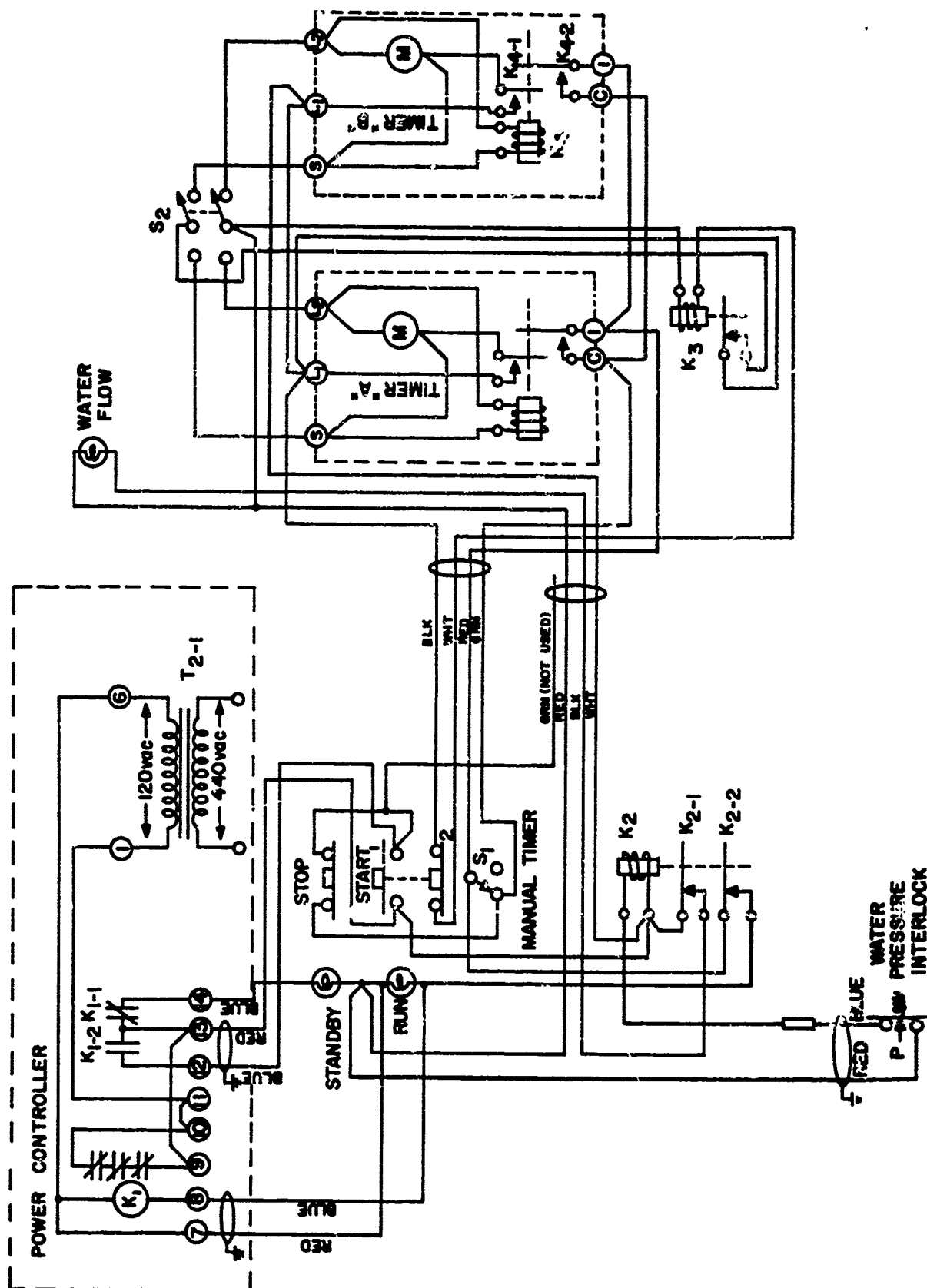
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FIGURE 7. Start/Stop Circuitry

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The water pressure interlock is normally closed energizing K_2, holding K_{2-1} and K_{2-2} open. Therefore, there is no path to close K_1. When the water is turned on, K_2 relaxes which arms the power circuit (through K_{2-2}) and lights the Water Flow indicator (through K_{2-1}).

With the water pressure interlock out, a run may be made in either a Timer or Manual mode as selected by the Switch S_1. Two timers with overlapping ranges provide accurate and continuously variable settings (Vernier Set, ATC Corporation). The range of timer "A" is from 0 to 15 seconds and the range of timer "B" is from 0 to 60 seconds. The Manual mode is normally used when the run time exceeds 60 seconds.

In the Manual mode, the Start button is first depressed to initiate a run. This closes the Start-1 circuitry, lights the Run light, and energizes K_1. This action (a) closes K_{1-2} to hold K_1 energized, and (b) opens K_{1-1} to turn the Standby light off. The run ends when the Stop button is depressed, which opens the circuit. This action (a) relaxes K_1, opening K_{1-2} and closing K_{1-1}, (b) turns off the Run light, and (c) through the closing at K_{1-1}, turns on the Standby light.

In the Timer mode, depressing the Start button lights the Run light, and relaxes K_3. The relaxing of K_3 closes its contacts, energizing timer relay K_4 of the selected timer through Timer Selector switch S_2. Energizing K_4 (a) closes K_{4-2} to hold K_1 energized, (b) energizes the preselected timer, and (c) holds the timer relay (through K_{4-1}). When the set period expires, an arm mechanically opens K_{4-1} to (a) relax K_4, (b) opening K_{4-2}, (c) which allows K_1 to relax. Depressing the Stop button, which corresponds to K_{4-2} opening, may also be used to end the run at any time. When the Stop button is pressed during a Timed run, the lamp circuit will open but the timer will continue until the pre-set value is reached. The lamp circuit cannot be re-energized until the Start button is again depressed.

In addition to the Timer Selector switch and two timers, the Timer panel contains a group of five panel lights. Illumination of each respective

panel light indicates (a) proper cooling water flow (b) secondary water system pump on (c) overhead blower on (d) radiometer recorder on (e) temperature recorder on.

SECTION IV

RECORDER CONSOLE

The recorder console shown in Figure 2 houses two strip chart recorders with a calibrated eleven inch chart width (Brown Electronic, Minneapolis-Honeywell Regulator Company). One recorder serves as a readout for the radiometer. The second is used for specimen or other temperature data gathering.

The radiometer recorder provides a radiometer history to insure proper operation during a run. The recorder is further applied in establishing exposure time, the irradiance rise time to and from peak load, irradiance transients during heating, proper settings (closed-loop set-point, open-loop percentage of maximum power, Thermac gain, etc.), and related information. The linear calibration is 0 to 10 millivolts and corresponds to the nominal radiometer range. The chart speed is 0.167 inch/sec.

The temperature recorder is calibrated for a Chromel/alumel thermocouple. The nonlinear range is from 0° to $1000^{\circ}C$. A total of sixteen chart speeds are available and range up to 0.667 inch/sec. In addition to recording specimen back-face temperature data, this instrument is useful in monitoring temperatures in critical areas.

SECTION V

PRIMARY FRAME

A large enclosure was constructed to house the reflector assemblies, high pressure water connections, and power cables. An overhead exhaust system further provides efficient ventilation and personnel protection from heat, light, noxious pyrolytic gases, and other potential hazards during operation.

The primary frame as shown in Figure 3 is of a rectangular configuration measuring approximately five feet in height by 4 feet in length by 2.3 feet in width. The frame was constructed as an open "box" from 3 inch angle-iron and then enclosed on three sides with one-inch thick asbestos/cement board (Transite, Johns-Manville). The frame front is open for ready access to components. The top is enclosed with a galvanized iron hood, which further supports a nine-inch diameter duct. A high velocity exhaust is provided by a squirrel-cage blower of 1500 cfpm capacity for dumping heat and gases outside the building.

A. Reflector Assemblies

Two reflector assemblies shown in Figures 8 and 9 share the primary frame. The assemblies are supported by slotted angle-iron grid-work just below the periphery of the exhaust hood. The assemblies further share cooling water and power interconnections as well as a railway for the reversible specimen table.

The first assembly is a high density radiant heater (Figure 8) which uses six quartz tube, tungsten filament lamps. The external periphery of the heater measures 12-3/4 inches in length by 3-1/4 inches in width. The effective working area, which is dependent upon the distance to the heated surface, is about 5 by 2 inches. These dimensions allow for radiometer mounting on the specimen table along the major axis and in the plane of the test specimen.

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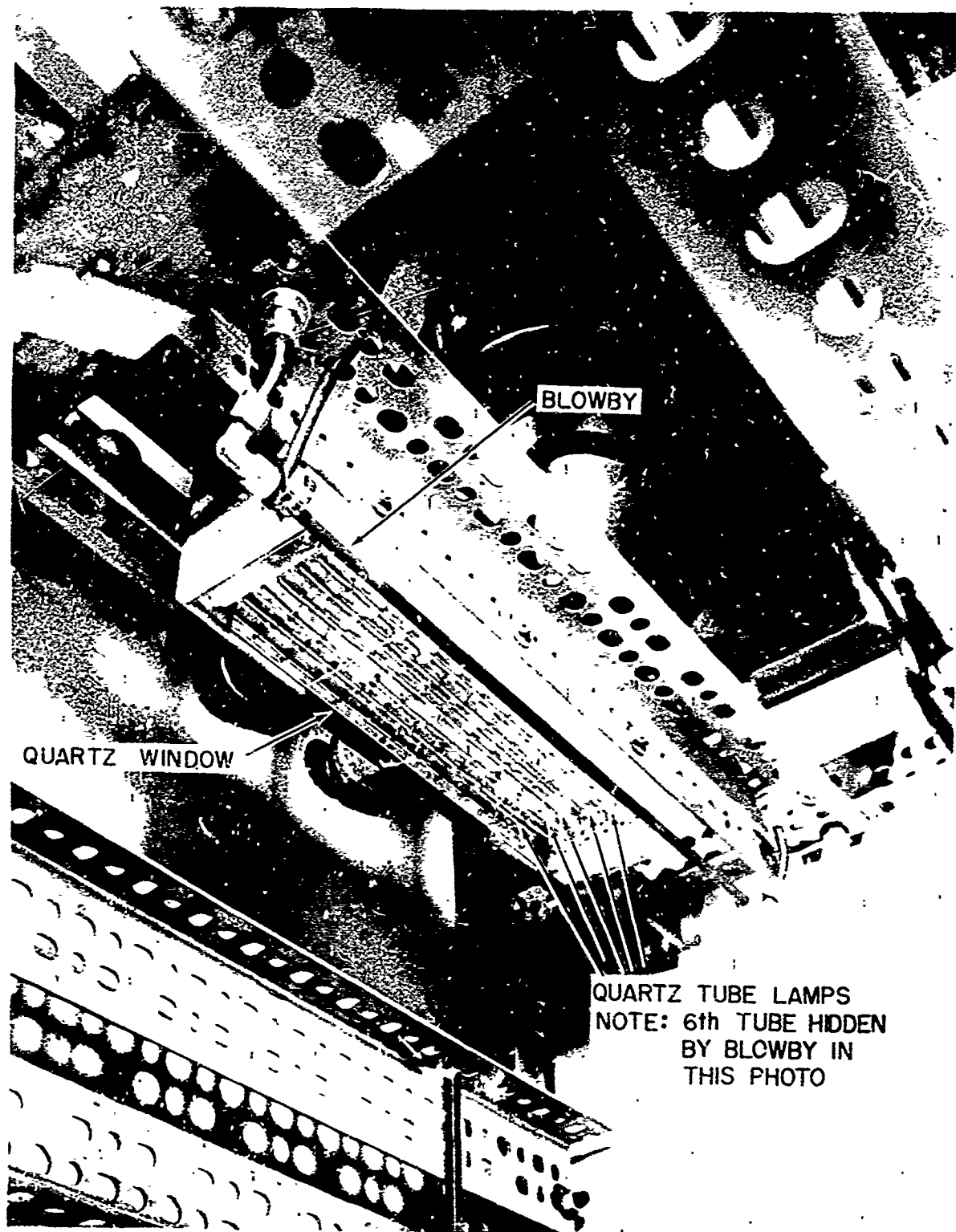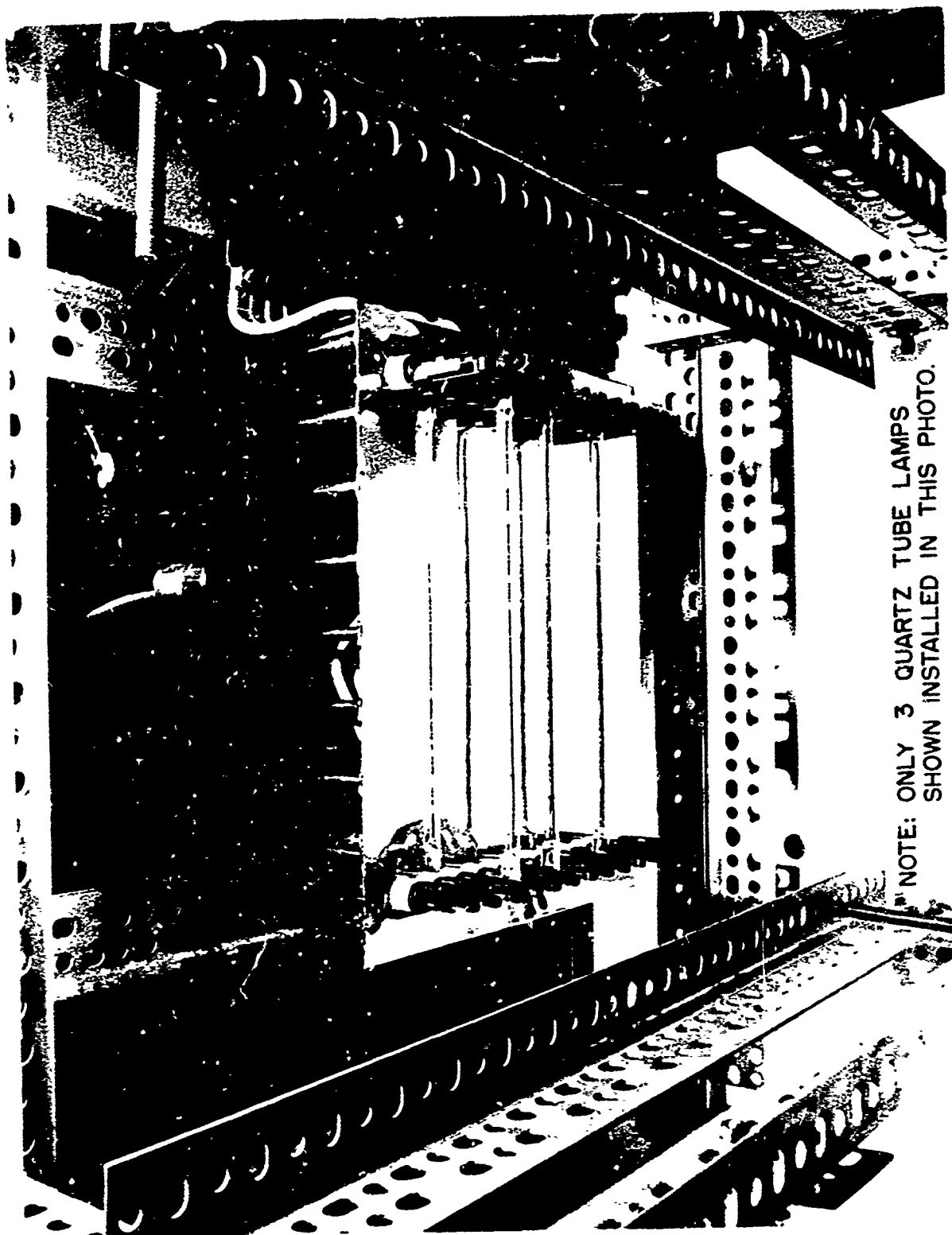
Labels on figure: BLOWBY · QUARTZ WINDOW · QUARTZ TUBE LAMPS / NOTE: 6th TUBE HIDDEN / BY BLOWBY IN / THIS PHOTO

FIGURE 8. High Density Radiant Heater

NOTE: ONLY 3 QUARTZ TUBE LAMPS SHOWN INSTALLED IN THIS PHOTO.

FIGURE 9. Reflector Panel

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With the six 240 vac clear quartz lamps normally used for the radiant heater, the rated capacity is 12 KVA. Quartz iodide cycle lamps, which feature a higher irradiance output and longer operational life-time, are also available. The rated capacity for six 480 vac iodide cycle lamps is 36 KVA. The nominal black-body temperatures at the rated voltage are $2150^{\circ}K$ for the clear lamps and $2210^{\circ}K$ for the iodide cycle lamps.

A number of unique design features are incorporated with the radiant heater to cool the lamps and avoid contamination by pyrolysis gases from nonmetallic material specimens. Contamination, combined with inadequate cooling at high irradiances, destroys the lamps and the aluminized surfaces of the heater.

The radiant heater was supplied with a quartz window. The window and thermally sensitive end seals of the lamps are cooled by pressurizing the housing with air. In the QLB, the external surface of the window is shielded by a fine film of air emanating from an adjacent blowby. The blowby consists of a 1/4 inch diameter length of copper tubing prepared with 0.040 inch diameter holes spaced 1/4 inch apart. The spacing is reduced to 1/16th inch in the vicinity of the radiometer for increased shielding. The exhaust hood complements the blowby patterns in minimizing window contamination.

The effectiveness of the blowby, exhaust, and pressurization was shown by lamp survival and reasonable suppression of window contamination for hundreds of runs.

The working area of the reflector panel (Figure 9) is varied with the number of lamps and their method of installation up to a maximum of about 13 inches in length by 7.5 inches in width. The area is reduced with the use of a radiometer, which requires about 1 square inch for installation.

The maximum rated capacity of the reflector panel is 48 KVA with 240 vac clear lamps. This corresponds to 24 lamps in a "double stacked" configuration. This number is reduced by one-half for a parallel bank of single lamps. The nominal available power from the line source is 132 KVA.

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Therefore, a full complement of 480 vac iodide cycle lamps is not practical at the rated capacity for this reflector assembly.

The reflector panel is primarily intended for specimens with minimum outgassing and has not been used with the nonmetallic materials of current interest. This application will require the development of suitable methods of shielding from contamination.

B.   Specimen Table

The specimen table (Figure 10) is essentially an inverted reflector panel with the aluminized surface facing the lamps. The table is protected from overheating by cooling water supplied from the primary water system by flexible, rubberized hose. In addition to serving as a primary support for the radiometer, the table can be readily modified to hold specimens of varying configuration by means of simple fixtures, openings for electrical leads or tubing, etc.

The table is retractable for easy access to the specimen or other components. The "drawer-like" action is accomplished by means of four Phenolic wheels riding on the railway. All components are accurately aligned to preserve the critical distance between the table and reflector. Latches permit locking the table in position.

C.   Radiometers

Two radiometers (Figure 11), manufactured by Medtherm Corporation of Alabama are currently available for the QLB. Similar in appearance and operation, the two instruments provide an operating range of 0-100 and 0-200 BTU/ft^2-sec[*].

The radiometers are of the Gardon-type which generate an electrical signal directly proportional to the thermal energy absorbed by the heat sensitive receiver. The installed radiometer is water-cooled by a 100 psig, high pressure water system (Figure 12).

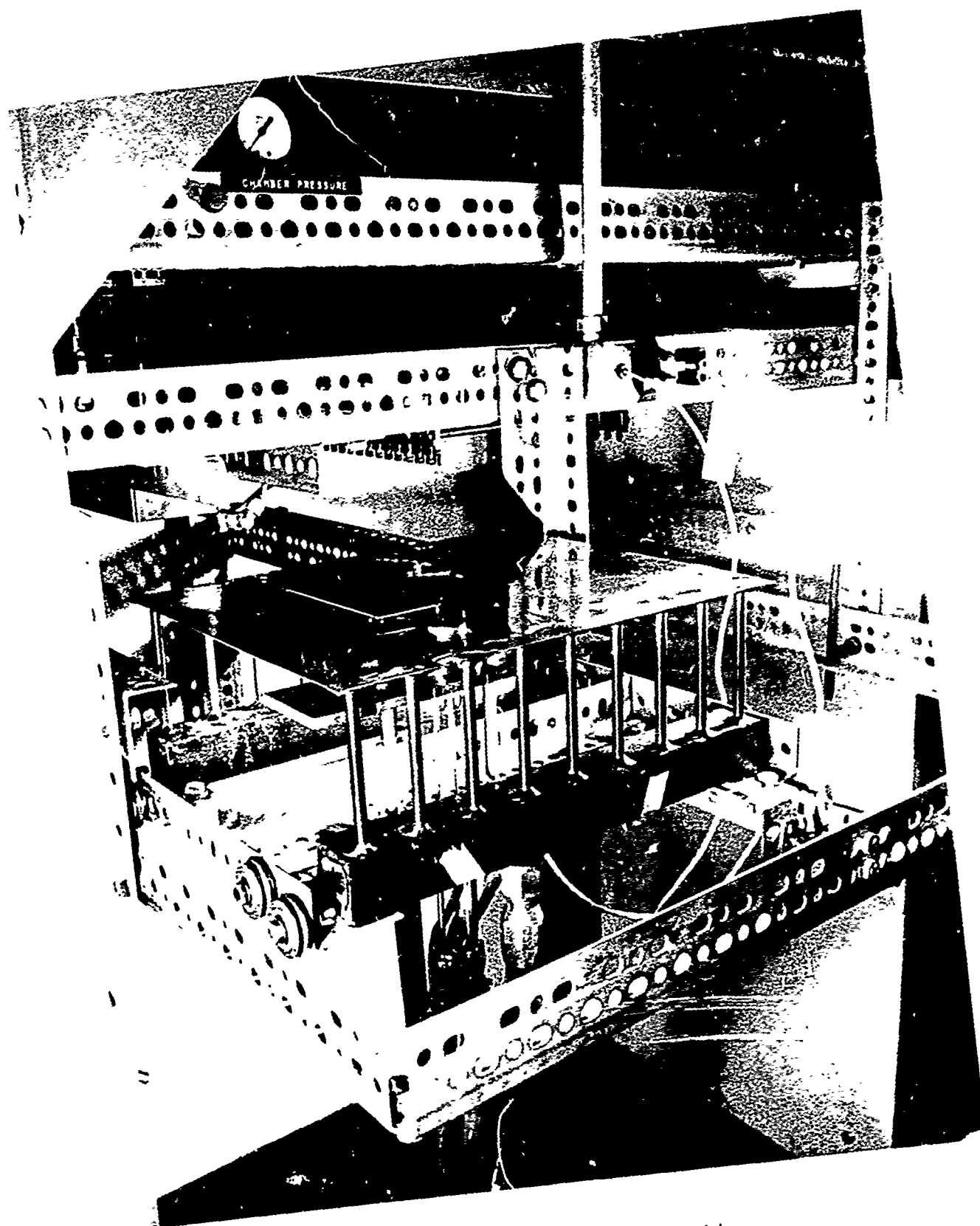[*]1 cal/cm^2-sec = 3.672 BTU/ft^2-sec.

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FIGURE 10. Specimen Table

FIGURE 11. Radiometers

RESERVOIR

HEAT EXCHANGER

FLOWMETER

PUMP

FILTER

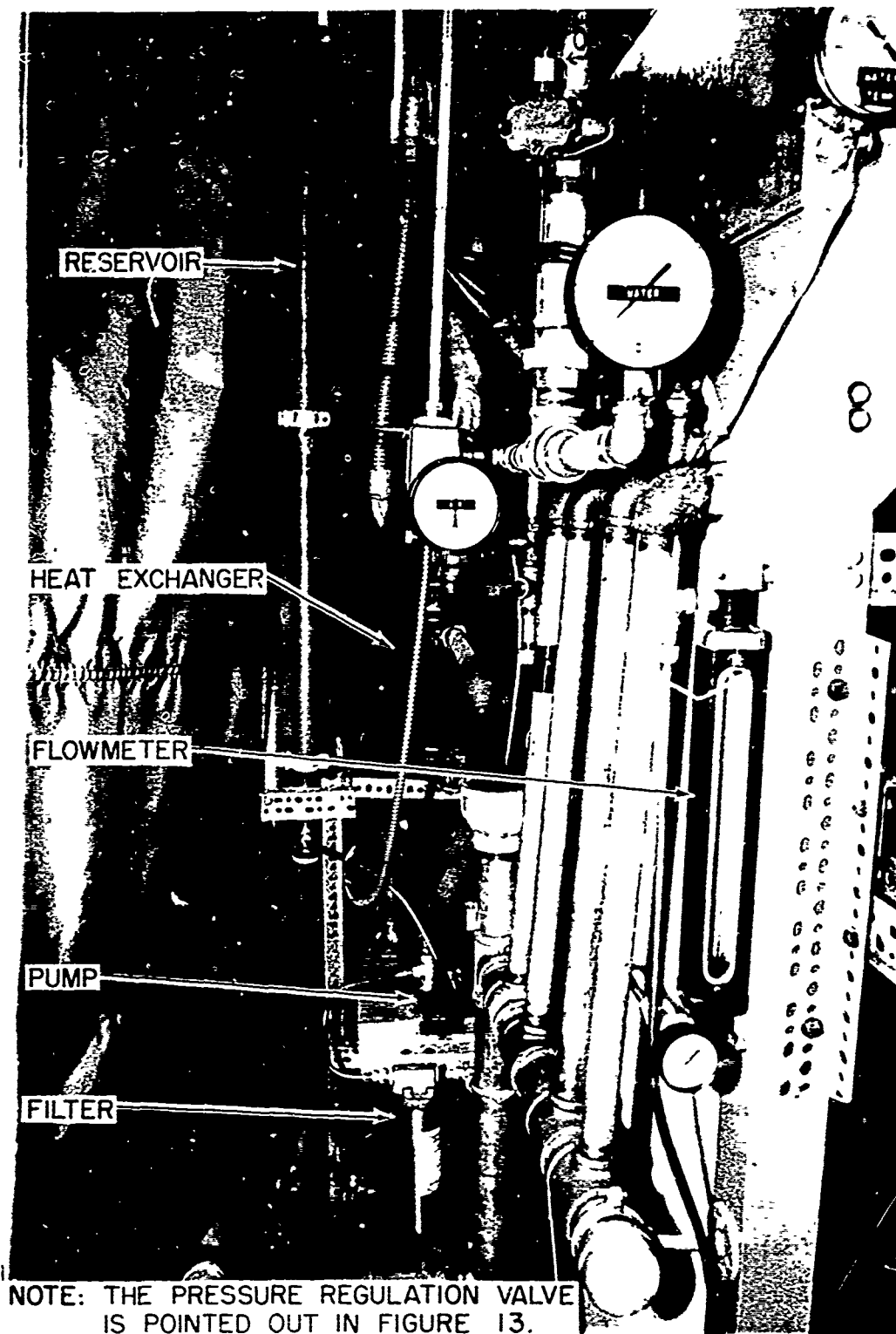NOTE: THE PRESSURE REGULATION VALVE
IS POINTED OUT IN FIGURE 13.

FIGURE 12. High Pressure Water System

The Gardon-type radiometer uses a sapphire window which results in a viewing angle of 150°. The window shields against convective heating, thus permitting the measurement of irradiance only. The external surface of the window is shielded from contamination by nitrogen purge (Figure 13) at a low rate and pressure from internal orifices. The radiometer body is further shielded by horizontal air flow from the radiant heater blowby.

The range of radiometer "A" is from 0 to 27 Cal/cm^2-sec (100 BTU/ft^2-sec) and the range of radiometer "B" is from 0 to 54 Cal/cm^2-sec (200 BTU/ft^2-sec)*. The corresponding linear dc emf output ranges are 0 to 9.7 and 0 to 8.13 millivolts for radiometers "A" and "B", respectively. The nominal performance features include an accuracy of $\pm$ 3%, overrange capability of 150%, repeatability of $\pm$ 1/2%, and response time of 100 milliseconds (full scale).

D.   Water Systems

There are two complete and independent water systems for the Q..B. The primary system cools the reflector assemblies and the specimen table. The high pressure system cools the radiometer.

Reference is made to a schematic representation of the primary water system (Figure 14). A swing-gate, 1/4-turn valve controls the line supply into an inlet manifold. Flow through one of the two reflector assemblies and the specimen table is controlled by three valves mounted on the manifold. The outlet manifold feeds the drain. The manifolds and the drain are mounted on one side of the primary frame.

The inlet manifold is instrumented with a pressure interlock switch and a pressure gauge. The switch opens shutting off lamp power (and the Timer panel indicator light, labeled "water") if the water pressure drops from the nominal pressure of 45 psig to below about 30 psig. The drain water temperature is also monitored using a closed-bulb meter. The temperature normally reads near 60°F with increases of up to 80°F with QLB operation.
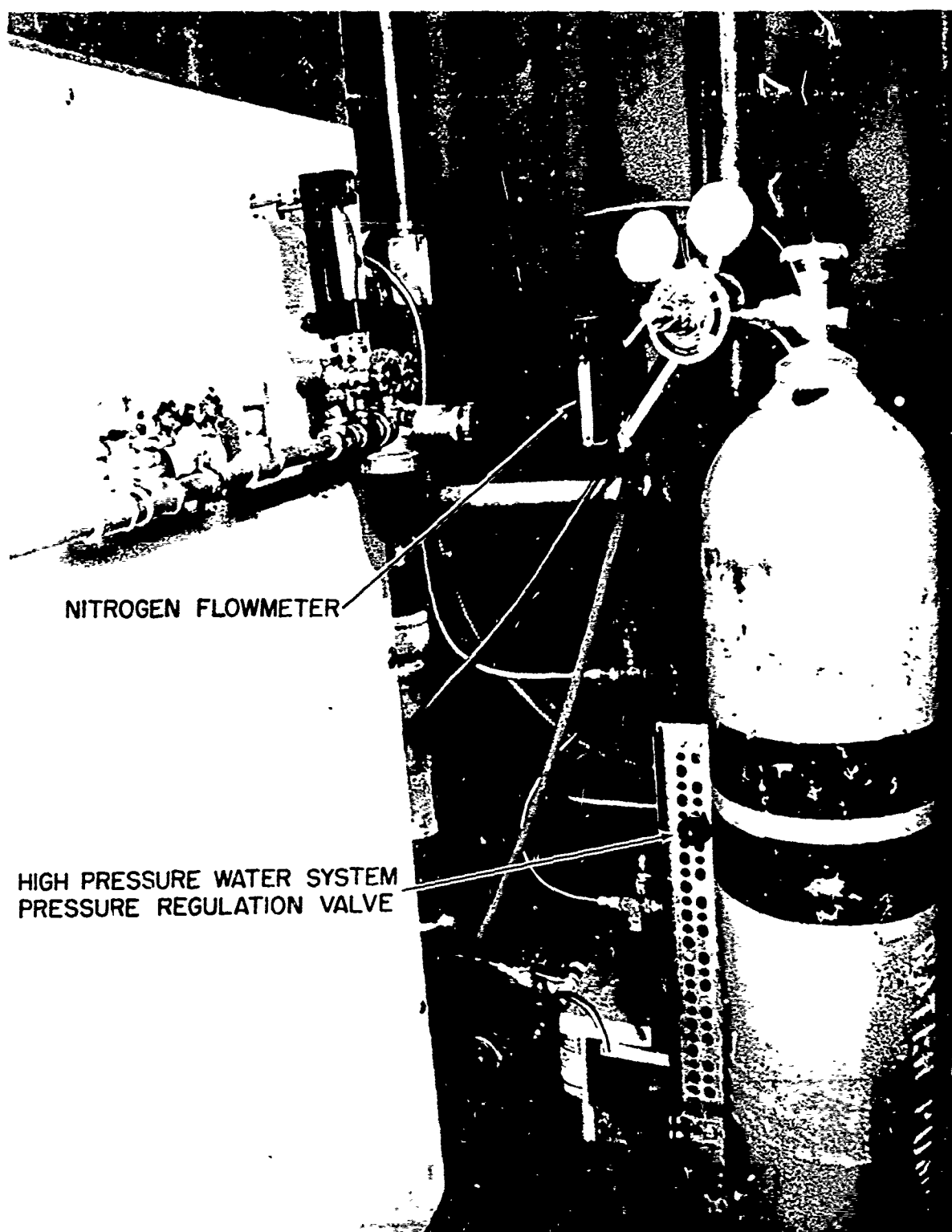
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*1 cal/cm^2-sec = 3.672 BTU/ft^2-sec.
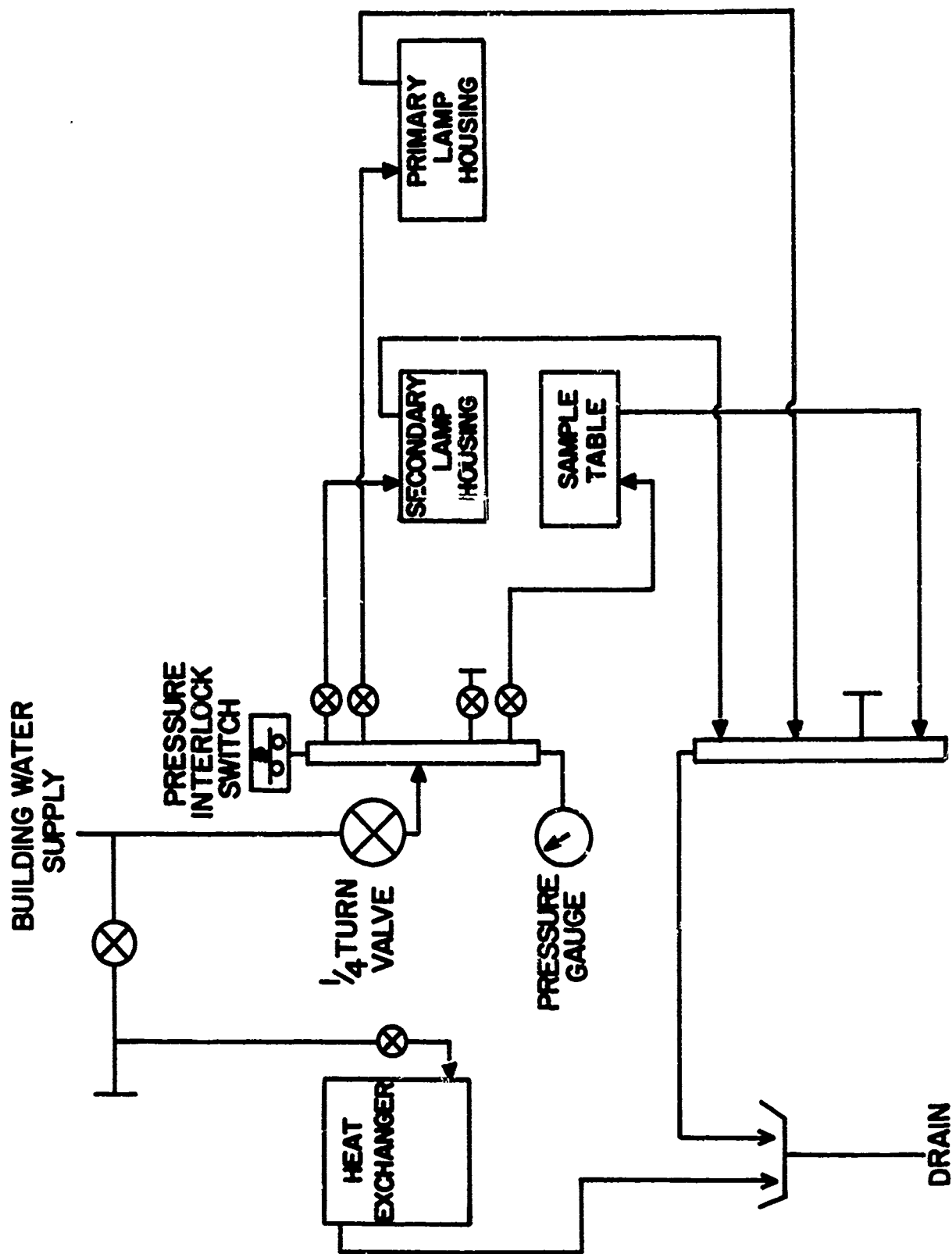
FIGURE 13. Nitrogen Purge System

FIGURE 14. Primary Water System Schematic

The design pressure for radiometer cooling is 100 psig and the actual flow rate is in excess of 2.5 gal/min. The rigid pressure requirement resulted in the design and construction of the high pressure water system.

As shown by Figure 12, the basic components of the high pressure water system consist of a pump, pressure regulation valve, filter, flowmeter, heat exchanger, and reservoir. The recirculating fluid is distilled water, which is further filtered to remove particulate matter. The heat exchanger was necessary to reduce water overheating.

E.   Air System

The central component of the air system is a manifold (Figure 15). A compressed air line supplies the manifold at a typical pressure of 80 psig. Filtered air is available from the manifold at a normal regulated pressure of about 40 psig.

The air system manifold normally supplies two components. The high density radiant heater is maintained at 10 psig chamber pressure for cooling of the lamps and the internal surface of the quartz window. The blowby is supplied at a typical pressure of 40 psig. The pressure is periodically monitored to assess any substantial fluctuations.

F.   Auxiliary Instrumentations

The primary auxiliary instrumentation consists of an ammeter (0 to 400 amperes) and a voltmeter (0 to 500 volts). These instruments, shown in Figure 2, originally installed in the Tri-Phaser, were relocated within the control console (Start/Stop circuit panel) for easier monitoring. Both meters are connected to a single phase of the 3-phase circuitry and only sense that single-phase characteristic during QLB operation.

A variety of additional instrumentation was installed to assist in preparing for a run, to assure proper and safe operation during the near immediate periods before and after the run, and to maintain reproducible

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COMPRESSED AIR LINE

BLOWBY FLOWMETER

BLOWBY VALVE

FILTER/REGULATOR

HIGH DENSITY RADIANT HEATER
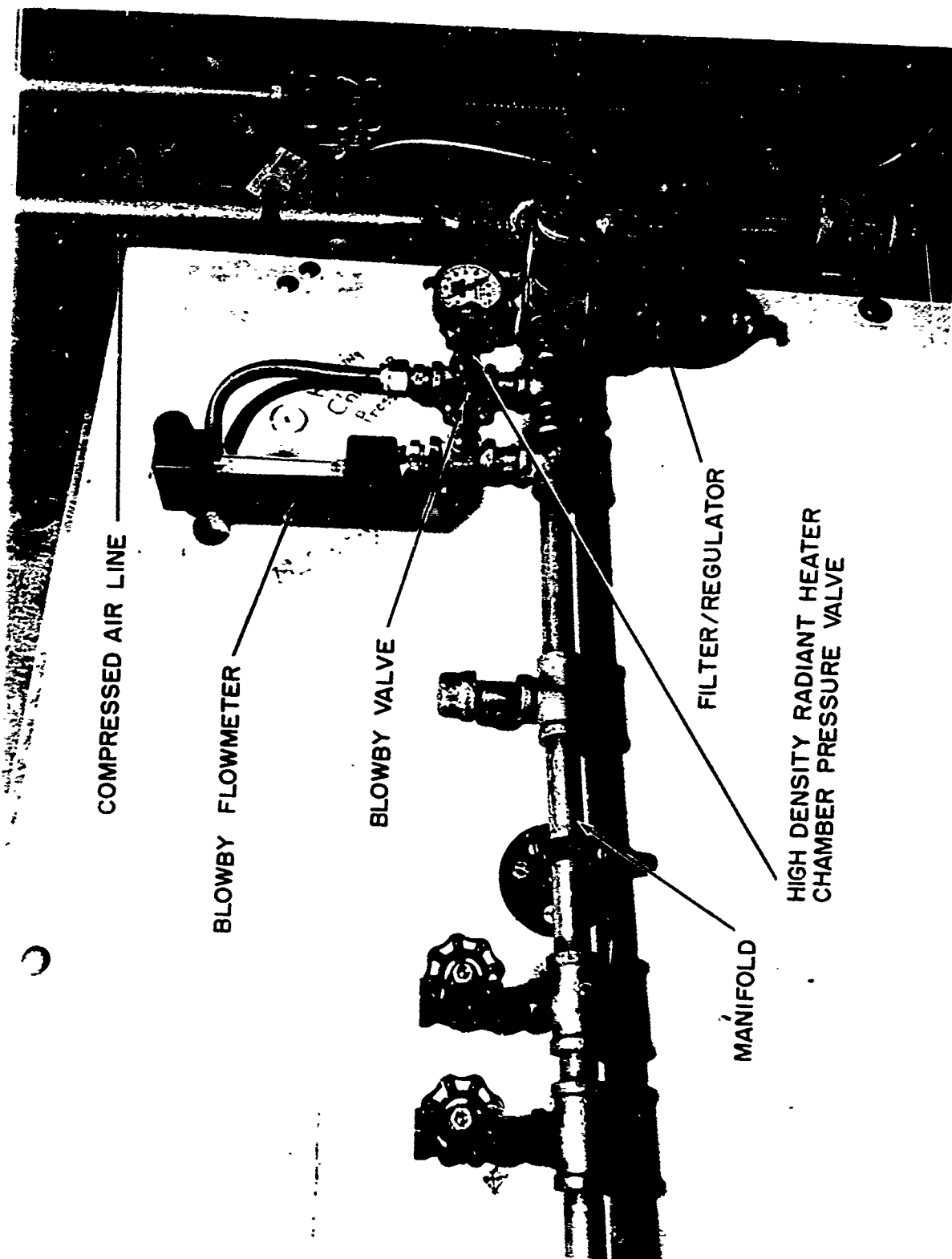CHAMBER PRESSURE VALVE

MANIFOLD

FIGURE 15. Air System Manifold

experimental procedures. The most important components were tapped to actuate an indicator light on the control console. Additional readout instruments installed include: pressure gauges for the air line (0 to 160 psig); high density radiant heater chamber pressure (0 to 20 psig) and radiometer nitrogen; water pressure gauges for the line (0 to 100 psig) and radiometer water pump (0 to 200 psig); temperature meters for the exhaust hood and water drain line (20°F to 180°F); flowmeters for nitrogen flow, air for the blowby, and water flow for the radiometer.

SECTION VI

TYPICAL OPERATION

A.   Introduction

The QLB was not designed as an integrated experimental apparatus. Instead, a number of modular units were used in the interests of economy and time. The complex interrelationships between the operating components can be more readily comprehended and visualized with the aid of a brief, sequential description of typical operation. The following description should not only prove useful for this purpose but should also meet two additional goals of aiding the planning of experiments and pointing out potentially hazardous elements of operation.

B.   Standby Operation

1.   The QLB is energized by closing a large safety switch disconnect (marked "Quartz Lamp Bank" and shown in Figure 4) into the "UP" position. Closing the disconnect applies power to the Tri-Phaser. In turn, (a) the Tri-Phaser fans start, (b) the Standby indicator light is lighted on the Start/Stop circuit panel, and (c) the Timer indicator (as selected by the Timer switch) is lit on the timer panel.

2.   The Thermac is turned on via the on/off switch located on the front of its panel.

3.   The Data-Trak is turned on as required via the mode selector switch located on its inside panel. Access requires opening of the door.

4.   The two recorders are turned on via on/off switches located on the lower inside of the chart-drive mechanism. Access requires opening of the door and then the mechanism.

5.   The (a) pump for the secondary water system for the radiometer and (b) overhead blower for the exhaust hood is turned on via two on/ off switches located on the top of the control console.

6. The line water supply is turned on via the swing-gate valve located at eye level on the left-hand side of the primary frame.

7. The air for the radiant heater is turned on via a valve designated "housing chamber pressure" and located at the rear of the primary frame. The pressure is manually set to 10 psig as indicated by the gauge located in the front of the primary frame and designated "chamber pressure."

8. The blowby air is turned on via a valve designated "blowby" and located at the rear of the primary frame. The flow rate is manually set to a midscale reading of the flow meter mounted on the valve.

9. The heat exchanger cooling water is turned on via a valve located at the lower front edge of the heat exchanger. The flow rate is manually set to maintain a low rate into the central drain.

10. The radiometer gas purge is turned on at a bottle located behind the main frame via (a) the main valve, and (b) a pressure regulator. The flow rate is manually set to the lowest numerical marking on the outlet pressure gauge and the rotameter.

11. The Manual/Timer switch located on the Start/Stop circuit panel is set in accordance with the run plan. For a Timer run, the specific timer is set with the timer selector switch located on the Timer panel.

C. Power Adjustment

The Tri-Phaser is connected in a manner to allow FAST application of power to the lamps. When in this mode, the system will tend to easily "overshoot" desired settings. The following procedure is recommended for the fastest application of power to lamps up to the desired level without overshoot.
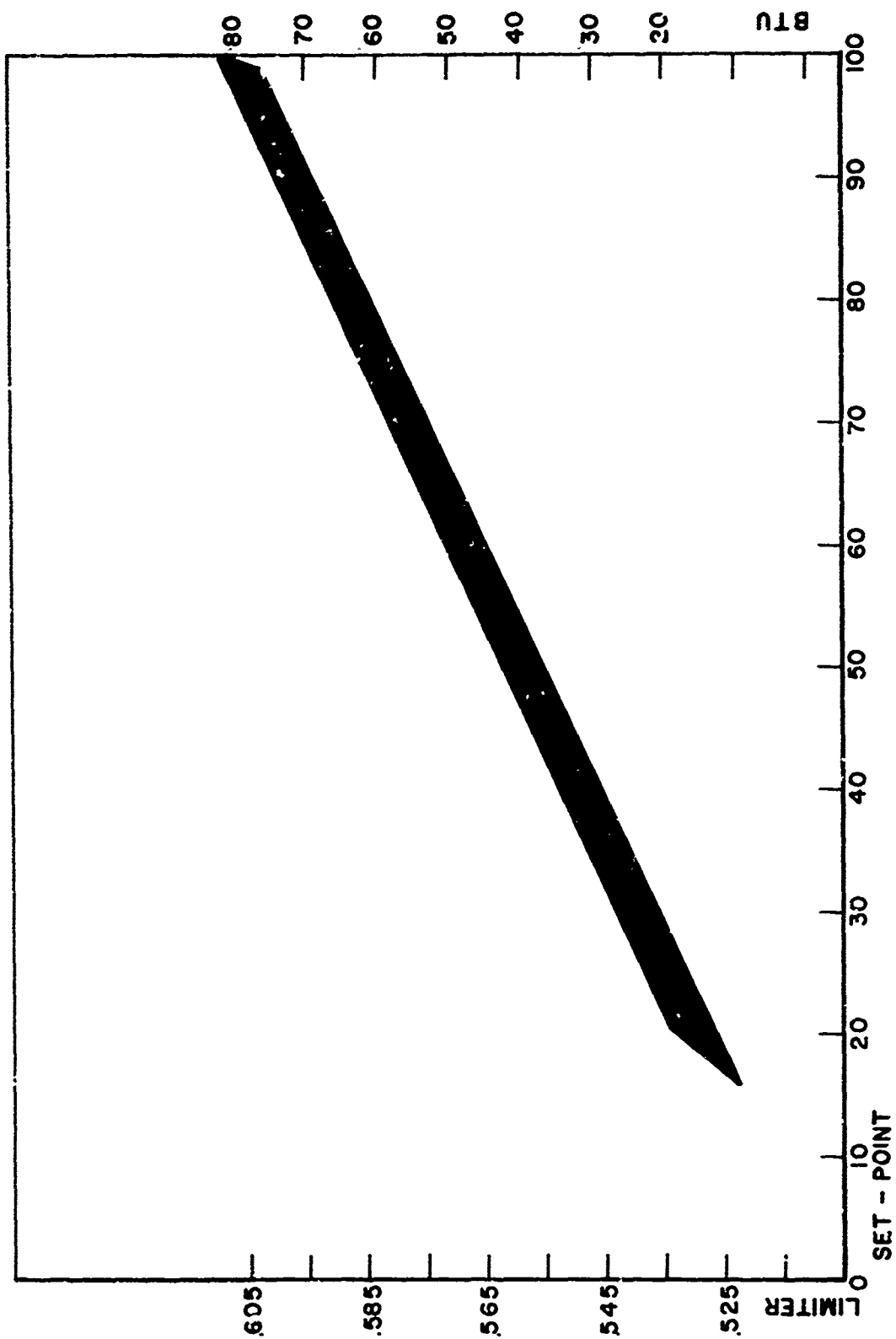
Figure 16. Limiter/Set-Point Graph

1. Place the Manual/Timer switch in Manual position. In
this mode the timer will still operate but will not extinguish
the lamps after the set time.

2. The Gain control on the Temperature Controller should
be set to about 5.5. This setting seems optimum for all
operations using the 0-100 BTU/ft^2-sec Gradiometer.

3. Put the Mode Selector switch in Set-Point position.

4. The Limiter should be set to some value below the value
indicated on the Limiter/Set-Point Graph (Figure 16) for the
desired irradiance.

5. The Set-Point should be set to some value above the value
indicated on the Limiter/Set-Point Graph for the desired
irradiance. The sample table with radiometer installed must
be beneath the lamp housing.

6. Depress the START button. (CAUTION: BE PREPARED
TO DEPRESS IMMEDIATELY THE STOP BUTTON IF THE
LAMPS ILLUMINATE.) The Run indicator should illuminate
and the Standby indicator should extinguish. If the lamps
illuminate or if the Run indicator does not extinguish, repeat
the procedure.

7. Slowly increase the Limiter by turning it clockwise until
the lamps come on. Turn the Limiter up until the desired
irradiance is indicated on Recorder "A."

8. Slowly reduce the Set-Point value while increasing the
Limiter value to maintain the desired irradiance. When
adjusting for the higher irradiances, exposure time should
be kept minimal to avoid overheating. Make adjustments
during short 'bursts" that would be similar to actual sample
exposure times.

9. Depress the STOP button. The lamps should extinguish.

10. Depressing the START button should now bring the lamps up to the desired level. If the level is overshot and oscillation occurs, the Limiter should be turned counterclockwise (ccw) and the set-point turned clockwise (cw). If the desired level is not attained quickly, turn the limiter clockwise (cw) and the set-point counterclockwise (ccw). Moving these two controls apart reduces oscillation and slows achievement of the desired level. Moving the Limiter and Set-Point closer speeds achievement of the desired level but produces oscillation. Note that the color and reflective properties of the sample will affect the levels attained and settings should be made with a sample in place if at all possible. Contamination on the lamp housing window can reduce attainable levels and greatly slow the speed of which a desired energy level is reached.

Caution must be exercised that the sample is not quickly destroyed. If sample life is too short to allow proper settings, a material with similar reflection properties but greater resistance to radiant energy should be used to at least get the settings close with final adjustments being made using short bursts.

SECTION VII
SUMMARY AND CONCLUSIONS

Efficient thermal protection materials are required by the Air Force to guard aircraft components and operating personnel from the intense thermal irradiance of ground fires and thermonuclear weapons.

In order to accommodate the wide spectrum of possible environments and specimen configurations in the exploratory research and development of a variety of nonmetallic thermal protection materials, the QLB was designed, assembled, and has been routinely operated for many hundreds of runs.

The QLB has provided high irradiances of up to 60 Cal/cm^2-sec for specimens of up to ten square inches in size with run times from 1 second to many minutes. Additional capabilities not fully exploited to date include 130 KVA available power for specimens of up to about 80 square inches.

The three operational modes consist of (a) a pre-set irradiance level, (b) precise regulation in a closed-loop network including a sensing radiometer, and (c) regulation over a programmed irradiance history.

Design features were adopted to cope with operational problem areas. For example, a variety of gas jets, a high velocity exhaust, and a pressurized lamp housing were used to avoid lamp overheating and minimize contamination by pyrolysis gases emanating from irradiated materials.

The QLB has proven to be an adaptable and versatile tool in the exploratory research and development of a variety of nonmetallic thermal protection materials. The classes of characterized materials currently consist of camouflage coatings, fire protection textiles, and protective coatings for components subject to thermonuclear irradiation.

SECTION VIII

SUGGESTIONS FOR FURTHER DEVELOPMENT

The QLB has proven an adaptable and versatile tool in the research and exploratory development of nonmetallic thermal protection materials for high irradiance environments.

Additional developmental areas for improved accuracy, reliability, and versatility include the following:

a. Completion of an interlock system for maximum safety during operation.

b. Comparative calibration of all available irradiance instrumentation.

c. Cine photography of the surface of a specimen.

d. Measurement of surface radiance and/or temperature of a specimen.

e. Measurement of the total fluence.

f. Measurement of the mean lamp color temperature.

g. Mapping of the irradiance and color temperature fields (horizintal and vertical) for the reflector assemblies as a function of input power (Thermac setting).

h. Mapping of rise time to peak load and cooling time for various operational arrangements as a function of input power (Thermac setting).

i. Families of Data-Trak programs for simulation of square-wave and programmed irradiance histories.

j. Environmental effects simulation methods (including specimen precooling and a high velocity air blowby).

k. Mechanical property characterization of a specimen during irradiation.

l. Development of a shielding blowby for the reflector panel.